ASSESSING THE FUTURE AND POTENTIAL FOR ADAPTATION OF ATLANTIC SALMON FACING CLIMATE CHANGE IN SOUTHERN EUROPE

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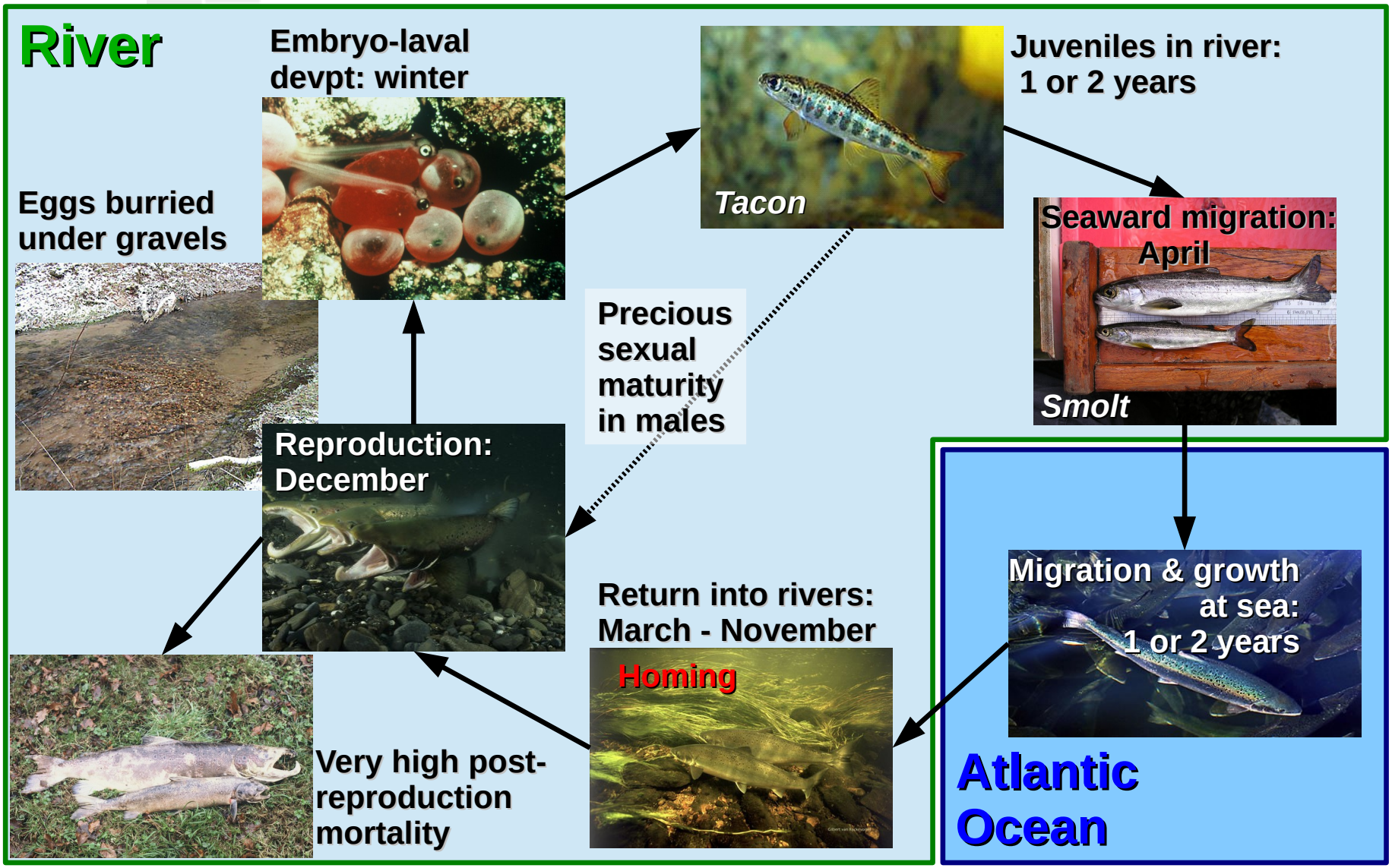
Atlantic salmon biological cycle



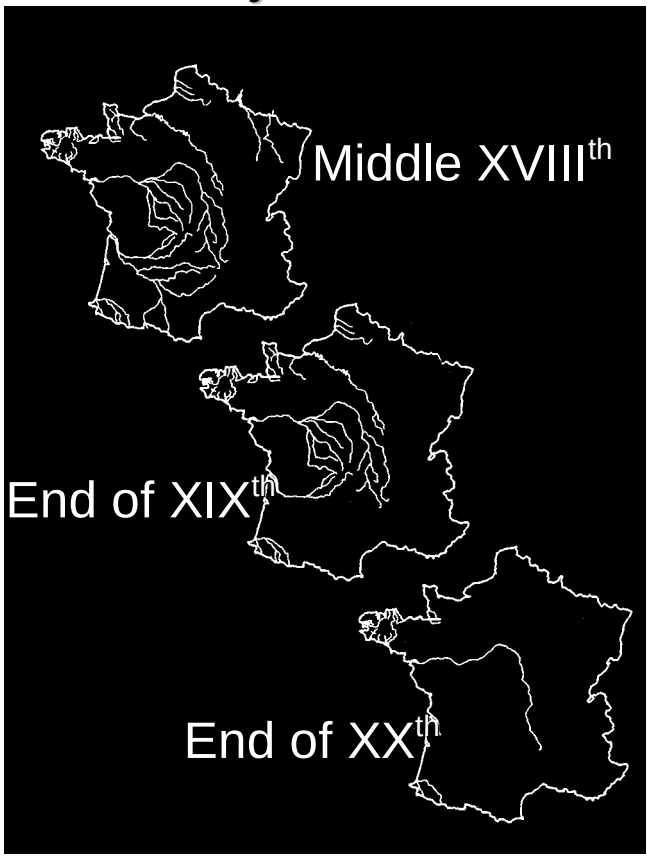
1 river -> (at least) 1 population: over 2000 populations in Europe

A natural heritage affected by human activities

- Damming → river fragmentation: main cause of population extinctions
- Physical & chemical pollution of waters
- Fisheries exploitation

→ *Salmon listed as threatened by EU Habitat Directive*

Evolution of the streams colonized by salmon in France



Climate Change : an additional stress in Southern Europe

- Salmon: a poikilotherm and cold water species
- France (& Spain): southern edge of species distribution

→ *Salmon could be strongly impacted by CC in Southern Europe*

- Salmon is an emblematic and threatened species

→ *Strong demand from society and management bodies for assessing the future and potential adaptation of salmon in front of CC*

Original pic from http://www.wiseass.org/

How to assess future CC effects on A. salmon at the local population scale ?

- Real world experiment: impossible
- In silico experiments with virtual population: the only alternative option?
  - Test diverse CC scenarios
  - Replication of experiments under a given CC scenario
  - Complementary to broad-scale approaches such as niche modelling that ignore behavioural and evolutionary processes
- INRA has developed a salmon population simulator for virtual experimentation of CC: IBASAM (Individual Based Atlantic Salmon Model)

  Piou & Prévost, 2012. Ecological Modelling, 231: 37-52

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IBASAM

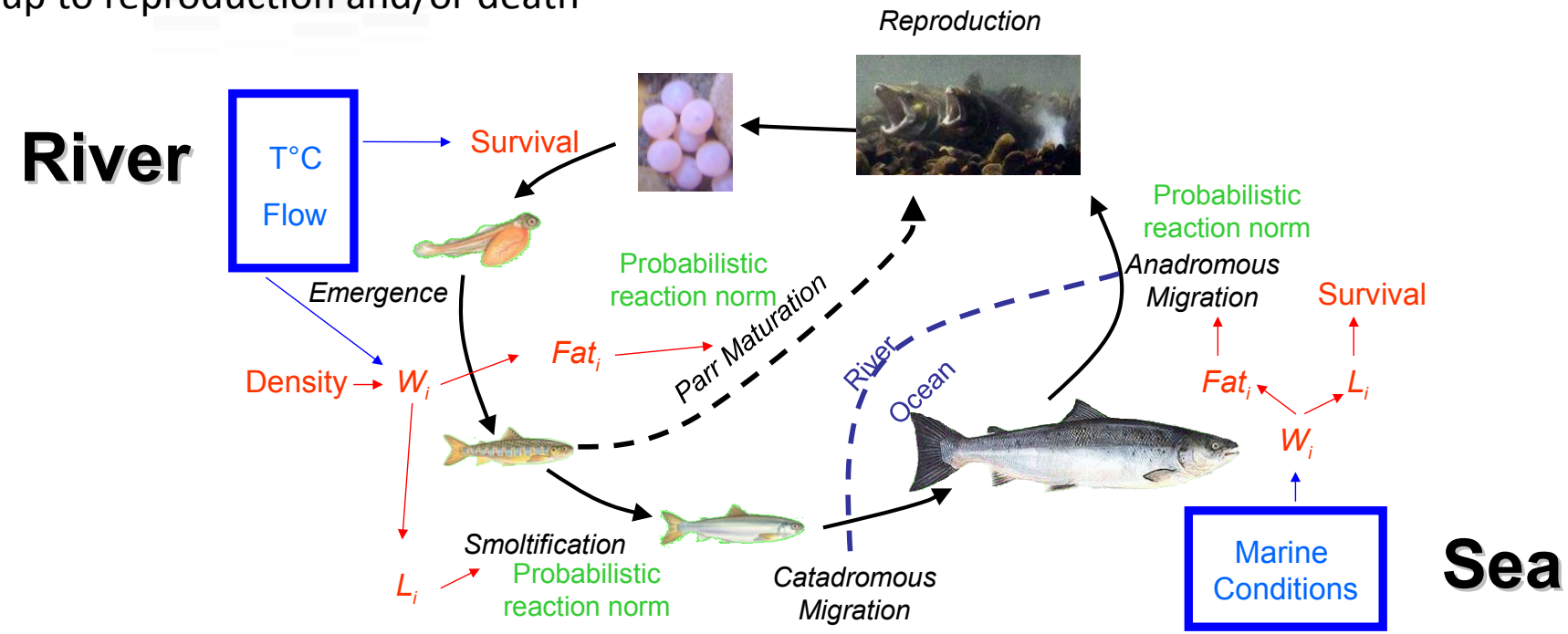
- Mimics a small population typical of french coastal streams
- CC is multiform
  - In rivers:
    - ↗ water T°
    - ↗ variability of flow
    - …
  - At sea:
    - ↘ conditions for growth
    - …

Original pic from http://www.wiseass.org/

- Connect demo-genetic dynamics with riverine (T°, flow) and marine factors (conditions for growth)

IBASAM

- Every individual of a population is explicitly represented and followed through its life up to reproduction and/or death



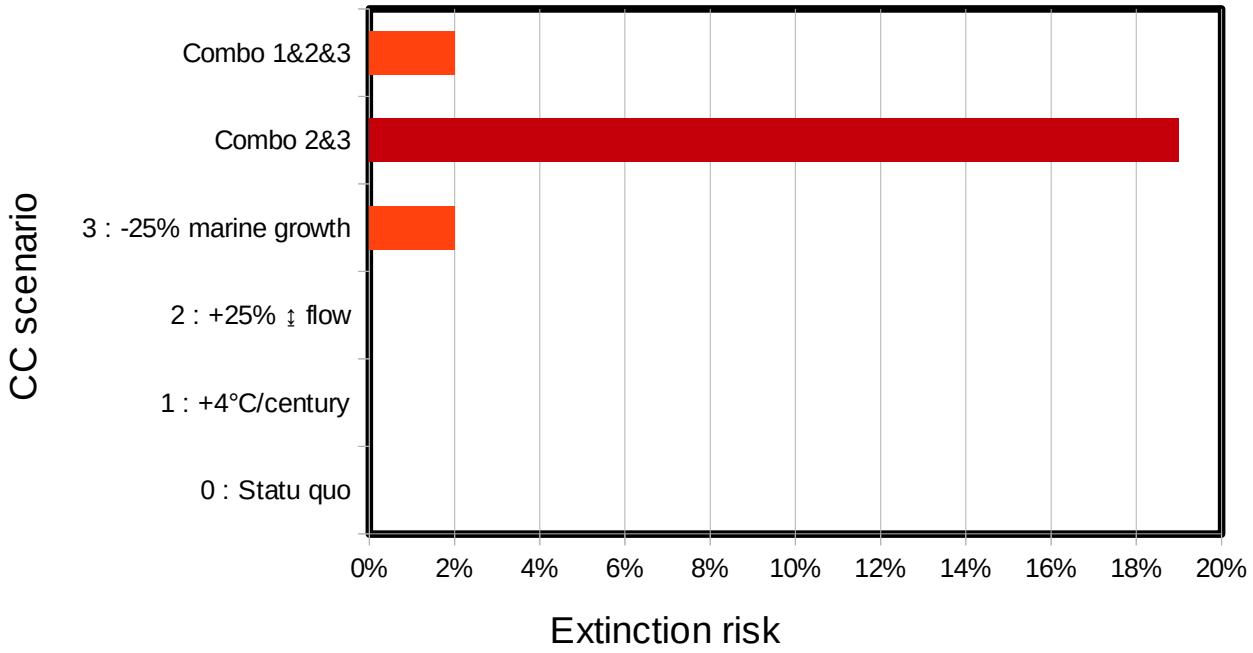
- Summarizes and articulates available knowledge on demo-evolutionary processes in A. salmon
  - Emphasis on the plasticity of the species: individuals adjust phenotype to yearly environmental variations
  - Explicitly represents individual genetic variability in the control of the plasticity mechanisms
  - Accounts for environmental and demographic stochasticity in population dynamics
- Calibrated against 15 years series of real population databases (Scorff river, Brittany, France)

First virtual experiments of CC with IBASAM
Combining riverine and marine changes

- 27 CC scenarios tested
  - ↗ river water T° (3 modalities)
  - ↗ river flow variability (3 modalities)
  - ↘ conditions for growth (3 modalities)

- Time horizon: 3 decades (~2045)
- 300 replicates per scenario
  - Initial size ~215 adults returning from the sea
    → small population

Potential CC effect on salmon population persistence



- Apart from worst case scenario, extinction risk is low at the 2045 horizon
- From the scenarios tested :
  - Marine conditions have the strongest effect
  - Synergetic effect of flow variability with marine conditions
  - ↗ river water T° mitigates the effect of the other 2 factors

First virtual experiments with IBASAM
CC & selective exploitation

- Selective exploitation is commonplace in salmon
  - Larger adults (maturing after 2 years at sea) are selectively harvested compared to smaller ones (maturing after 1 year at sea)
- CC and selective exploitation occur simultaneously → How to compare their respective effects while assessing their interactions?
- A virtual experimentation plan: 5 CC scenarios X 5 exploitation scenarios
  - CC → only ↘ conditions for growth (main driver of CC effects)
  - Time horizon: 3 decades (~2045)
  - 30 replicates per scenario

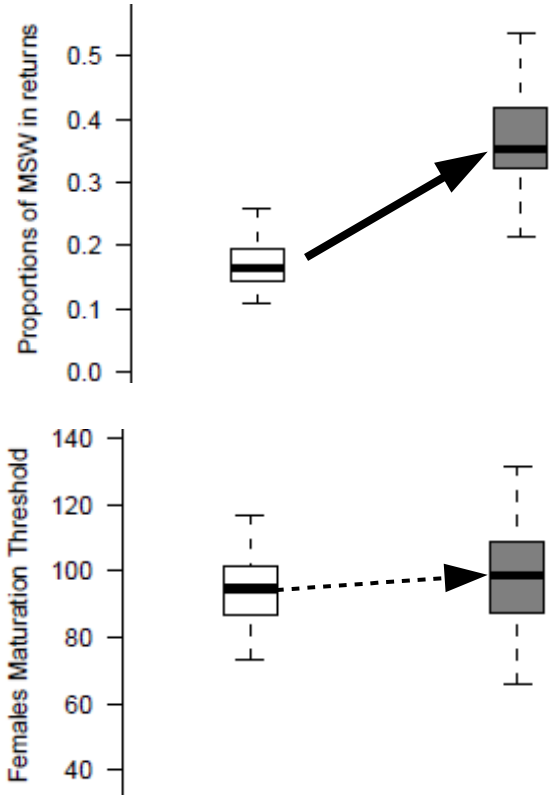
CC vs selective exploitation
Phenotypic plasticity vs genetic evolution

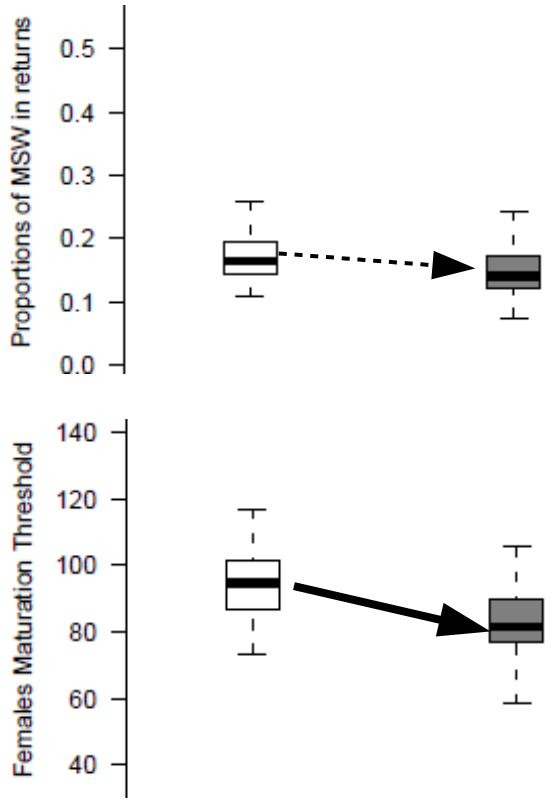
CC only
↘ 25% growth at sea

Selective fishing only
15% expl. rate 1 year at sea
↗ expl. rate 2 years at sea 15→75%

Phenotype
Prop. 2 years at sea

Genotype
Genetic threshold triggering sexual maturation in females



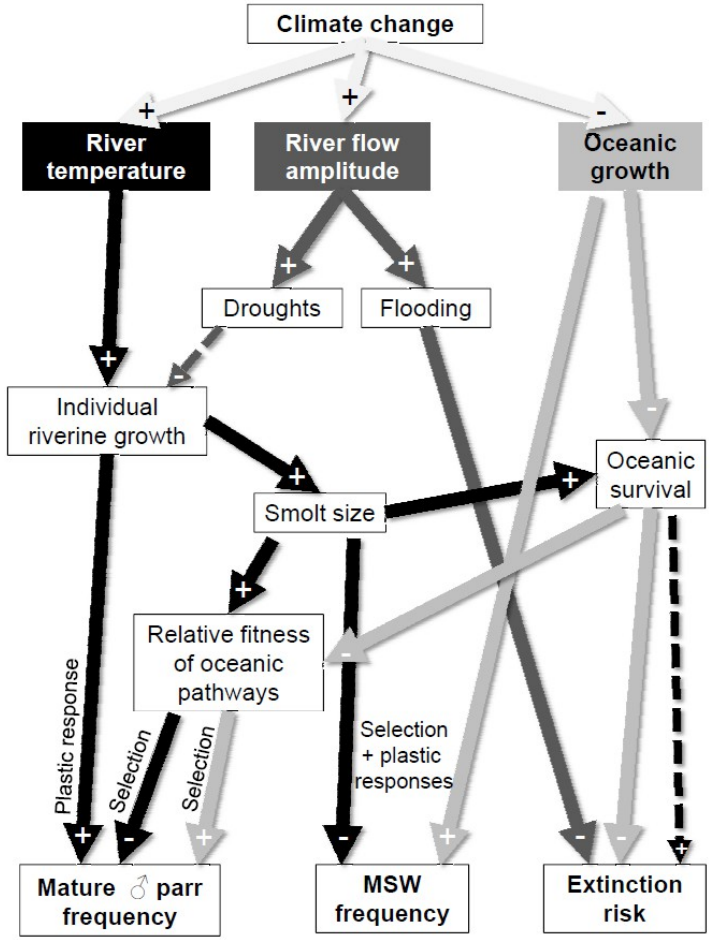


Mostly plastic response
Little genetic evolution

Stronger genetic evolution

Assessing the future of A. salmon in front of CC
IBASAM: a tool for making scientific progress

- Demo-genetic simulation (and IBASAM): a powerful approach to explore CC consequences on A. salmon populations
- Cannot be appraised by mere intuition
- The effects of CC are mediated by a complex array of interacting biological traits which outcome is the resultant of contradictory forces
  - IBASAM: a tool for better understanding of these interactions



Assessing the future of A. salmon in front of CC
Where are we now ?

- Lack of understanding → any prediction is currently surrounded by (too) broad uncertainty (to be useful)
  - Acknowledge Science has still little to say to advise managers: despite strong demand for answers science must be cautious not to oversell prelimanry results
- Assessing potential consequences of CC on A. salmon: just the beginning
  - IBASAM: considerable room for improvement
- Not at the edge of population extinctions even in Southern Europe → must take advantage of the next two decades to improve scientific advice to A. salmon population management
  - Reduce prediction uncertainty
  - Conceive management options that are robust to uncertainties
  - *Adapt (management) to foster adaptation (of A. Salmon populations)*

Future of A. salmon in front of CC

From impact assessment

→ management for adaptation?

- Beyond the next 3 decades: pure plasticity might not suffice for population persistence in front of CC
- Rapid genetic evolution might be needed as well
- First virtual experiments with IBASAM suggest:
  - Plasticity dampen and could slow down genetic evolution in A. Salmon
  - Selective exploitation could drive rapid genetic evolution

  Explore the potential of intentionally selective exploitation to foster evolution favoring adaptation of A. salmon populations to CC
- SALMOCLIM: a research project to address this issue
  - Funded by INRA under its Meta-programme ACCAF on Adaptation to Climate Change of Forest, Agriculture and Aquatic Ecosystems

Thanks for your attention !